10

Management of the Stiff Hand

Robyn Midgley

INTRODUCTION

This chapter explores the complex topic of joint stiffness and details the innovative, evidence-based solutions that could transform your therapeutic strategies. The goal is to provide awareness of the knowledge and tools required to optimize patient care in a time efficient and cost effective manner. This chapter serves as a foundation for understanding and treating the stiff hand comprehensively, considering, tissue tolerances, healing timelines, and the body's intricate interconnections.[1]

UNDERSTANDING THE STIFF HAND

Key Potential Causes of Joint Stiffness

To comprehend the complexities of the stiff hand, we must re-evaluate hand anatomy and delve into the contributors to joint stiffness at histological, chemical, cerebral, and mechanical levels. This section establishes a foundation by emphasizing tissue stress concepts on healing timelines and their impact on transforming our approach to joint stiffness.[2,3] The understanding gained here will lay the groundwork for the subsequent case studies.

The hand is a complex structure of bones, joints, ligaments, tendons, muscles, nerves, and blood vessels that function in perfect harmony. A disruption to any of these elements can lead to acute joint stiffness and abnormal movement. If not swiftly and effectively addressed, acute stiffness may become chronic, complicating treatment and risking irreversible functional impairment.[1]

Creating an effective treatment strategy for stiffness hinges on more than just identifying the underlying cause or determining the stage of stiffness—acute or chronic. It also requires understanding the role of the somatosensory cortex in creating abnormal motion patterns, often leading to the inadvertent immobilization of the stiffest joints.[1]

A comprehensive assessment is crucial for developing an effective treatment plan for a stiff hand. Scientific knowledge of connective tissue integrity, particularly collagen and elastin, underpins the understanding of how these tissues contribute to the hand's strength, flexibility, and overall biomechanics. This knowledge guides the clinical assessment and treatment strategies necessary to navigate the complexities of joint stiffness.

Patients with hand injuries are susceptible to joint stiffness and significant functional loss due to the interconnected nature of the hand's structures. Injuries can indirectly affect adjacent tissues, especially when prevention is not adequately prioritized. To address this, post-operative protocols focus on early active motion to prevent abnormal movement patterns. Therapeutic intervention extends beyond the treatment room, encouraging a daily environment of repetitive, continuous, and intentional movement to effectively prevent or improve joint stiffness.

Understanding joint stiffness involves multiple fundamental concepts that span across various biological and lifestyle factors. The anatomy and physiology of tissues, including muscles, ligaments, and tendons, are crucial, as injuries or dysfunction in these tissues can lead to stiffness. Inflammation, whether chronic or acute, contributes significantly by causing fluid buildup in the joint or altering surrounding tissues. Trauma, mechanical injury, or strain may initiate scar tissue formation, reducing the joint's range of motion. Fibroproliferative conditions, such as Dupuytren's disease, can cause joint contractures requiring surgical intervention, with excessive orthotic use or therapy potentially worsening stiffness. Neurological factors also play a role, as changes in the brain and nervous system can lead to perceived or actual joint stiffness. Aging naturally contributes to stiffness through degenerative processes, while autoimmune conditions like rheumatoid arthritis and systemic diseases such as diabetes or hypothyroidism can exacerbate stiffness through immune responses or other systemic effects. Metabolic syndrome, associated with chronic low-grade inflammation and insulin resistance, may also affect joint health. Lifestyle factors, including lack of exercise, poor posture, obesity, and repetitive movements, contribute to muscle fatigue and stiffness. Additionally, some medications can induce stiffness as a side effect.

Collagen and Elastin

Collagen and elastin are two important proteins that greatly contribute to the mechanical properties of connective tissue Collagen, the most abundant protein in the body, provides the tensile strength required for tissue tolerance to stretch. Elastin provides the tissue with the elastic ability to return to its original shape following stretching or deformation. Elasticity is essential for the dynamic movements and flexibility of the hand.[4] The relative abundance and arrangement of collagen and elastin varies and affects the viscoelastic behavior of specific connective tissue.[4]

BIOMECHANICS OF SOFT TISSUES

The biomechanics of the soft tissue in the hand involve intricate design and delicate balance. The **viscoelastic** properties of the soft tissue refers to the viscous nature, akin to a fluid, while "elastic" denotes the ability to spring back to their original form, similar to an elastic band. These dual properties allow the hand to respond effectively to an array of mechanical loads and stresses, safeguarding its functional utility and structural integrity.[4]

When a force is applied to the soft tissue during normal hand movement, both the viscous and elastic components are engaged. The viscous element allows for slow deformation and energy dissipation, making tissues resistant to sudden changes in force or strain rate. Concurrently, the elastic component provides the ability to recover its original shape and size upon removal of the applied force.[4]

VISCOELASTIC BEHAVIOR OF TISSUE

Viscoelasticity, a foundational characteristic of connective tissues, allows for both fluid-like deformation and elastic recovery. When a load is applied to a tissue, it initially deforms like a viscous fluid and returns to its original shape like an elastic solid. This property is crucial for shock absorption and resisting deformation during movement. Viscoelastic behavior changes over time and is influenced by factors like strain rate, age, temperature, and pathological conditions.[5]

Joint stiffness alters viscoelastic behavior, leading to restricted mobility and resistance to movement. This is caused by persistent edema, the stage of wound healing, collagen cross-linking, muscular shortening, and certain traumatic or fibroproliferative conditions like Dupuytren's disease.[6]

The viscoelastic behavior also explains the phenomena of creep (elongation of tissue under a constant load) and stress relaxation (decrease in stress under a constant deformation), which are components of stretching and mobilization techniques in hand therapy.[1]

Understanding viscoelasticity, tissue tolerance, and healing timelines is essential to formulating therapeutic interventions based on tissue response to the rate, type, and application of loading and to avoid aggressive treatment. Light pressure application, pain avoidance, passive range of motion exercises, and facilitating tissue glide with careful immobilization or active joint movement, ensure respectful treatment of the tissue.

COLLAGEN CROSS-LINKING

Collagen cross-linking happens both within a single collagen filament, forming weak intra-molecular links between amino acid chains, and between different collagen filaments, creating strong inter-molecular links that lock them together. When an injury happens, the tissue responds by producing new collagen, the protein building block of most tissues. The new collagen is typically not as well-organized or as stretchy (elastic) as the original, mature collagen. It also has fewer cross-links (bonds between the collagen fibers), which makes it weaker. The lack of organization, elasticity, and strength contributes to stiffness in the affected area.[1]

Conversely, when a joint is immobilized for an extended period, the collagen in the area forms more cross-links than usual. While cross-links are a normal part of collagen structure, excessive, insufficient, or abnormal cross-linking all potentially lead to stiffness. When the cross-links bind the collagen fibers together too tightly, flexibility and normal sliding motion are restricting. Abnormal cross-linking reduces differential glide, the ability of different tissue layers to move against each other further contributing to stiffness.[7] Joint stiffness can therefore be caused by two related but different processes: the production of new, disorganized collagen in response to injury, and the excessive cross-linking of collagen due to immobility. Both processes affect the structure and behavior of collagen, an important component of joint flexibility.

THE ROLE OF NEUROPLASTICITY

The motor cortex, a key brain region for controlling movement, reorganizes or "repatterns," in response to changes in motor demands, a process critical for learning new skills or adapting existing ones.[8] Reduced activity in this area, is seen in conditions like stroke, impaired movement, and coordination. Neuroplasticity, the brain's ability to adapt based on experience, is crucial for motor learning and recovery post-injury. For instance, disuse of a hand due to injury can result in changes to the motor cortex that impairs hand function. However, cognitive engagement during hand exercises stimulates the creation of new neural connections, potentially improving hand function by activating additional brain regions involved in motor control. In essence, motor cortex repatterning, cortical activity, and neuroplasticity all play integral roles in both the learning of new motor skills and the rehabilitation of motor function after injury.[8]

CLINICAL ASSESSMENT

The development of an effective treatment strategy begins with a comprehensive assessment. This includes gathering patient history, performing a thorough physical examination to determine whether the joint stiffness is acute or chronic (evidenced by a hard or soft end feel), identifying the stage of wound or tissue healing, and considering contributing factors such as previous injury, persistent edema, the presence of infection, inflammation, or pain. It is important to analyze the pattern of joint motion and perform a functional evaluation. Additionally, a holistic understanding of joint stiffness also involves investigating the impact of injured tissue on surrounding tissue and the role of the sensory motor cortex. This multi-faceted approach aids in obtaining a complete picture of the patient's condition and consequently informs the most suitable treatment plan.

PHASES OF TISSUE HEALING

Tissue healing follows three stages, with specific characteristics and duration.[9] The three phases are:

1. The **inflammatory** phase is the immediate response to tissue injury, and lasts up to 72 hours post-injury. During the inflammatory phase, blood vessels at the injury site constrict to control bleeding (hemostasis), then dilate to allow immune cells, such as neutrophils and macrophages, to reach the site of injury. These cells initiate the clean-up process by **phagocytosing** bacteria and dead cells, releasing substances to recruit more immune cells to the site. Vasodilation and increased vessel permeability lead to the classic signs of inflammation: redness, heat, swelling, and pain.
2. The **proliferative** phase starts at 3 days post-injury and lasts up to 3 weeks. The proliferative phase is characterized by proliferation of fibroblasts (cells that produce collagen and other extracellular matrix components), the development of new blood vessels (angiogenesis), and the beginning of wound contraction, resulting in the formation of granulation tissue and a scar matrix as a temporary form of tissue repair.
3. The **remodeling** phase begins at 3 weeks post-injury and lasts up to a year or more, depending on the extent of the injury. During the remodeling, the disorganized collagen fibers formed during the proliferative phase are gradually remodeled to become organized and stronger fibers. There is also a reduction in blood vessel density and a continuation of wound contraction resulting in a stronger, more organized scar. Scar tissue never reaches the full strength of the original tissue.

Each phase of healing is a part of an integrated process, with overlap of the stages. It is important to note that the timing and progression of each phase varies depending on multiple factors, including type and severity of injury, tissue involved, patient's overall health, and effectiveness of the interventions used during the healing process.[9] The case studies described below illustrate how the phases of healing are incorporated into clinical reasoning and treatment planning, with Tables 10.2A, providing specific demonstrations of these concepts.

TISSUE TOLERANCE

Tissue tolerance refers to the ability of a given tissue to withstand or respond to the demands or stresses of normal daily activities or therapeutic interventions. Each type of tissue in the body has a different level of tolerance, which is affected by a variety of factors including the health of the tissue, stage of healing, patient's overall health status, and presence of disease that may impact tissue health.[10]

Assessing tissue tolerance involves objective and subjective measures:

- **Pain** is the most common subjective measure used to assess tissue tolerance. Patients report discomfort, pain, or aching in the area assessed. Pain may occur during or after activity or therapy. A change in pain pattern (i.e., increased intensity, duration, or frequency) signifies that a tissue's tolerance was exceeded.
- **Swelling** (edema) is an objective measure of tissue tolerance. An increase in swelling after activity indicates that the tissue tolerance was surpassed.
- **Mobility** changes in a joint or tissue's range of motion also provides clues about tissue tolerance. For example, an unexpected decrease in mobility after activity suggests that tissue tolerance has been exceeded.
- **Function**al assessment of how well the patient performs certain tasks or activities provides insight into tissue tolerance. An inability to perform tasks that were previously manageable suggests that tissue tolerance was exceeded.
- Any unexpected decrease in muscle **strength** following activity may indicate that tissue tolerance was exceeded.
- Changes in skin **color and temperature** indicate changes in tissue tolerance.

During therapy, it is important to adjust the treatment plan accordingly based on any changes in signs and symptoms. When a particular intervention or exercise appears to be exceeding tissue tolerance, the treatment plan is modified or eliminated to prevent further injury and promote healing. Photo and video documentation at each session is helpful in establishing baseline status, measure progress, and analyze changes in tissue tolerance. Tables 10.2A,B and 10.3 demonstrate application of treatment plans with consideration for tissue tolerance.

PROPRIOCEPTION

Proprioception refers to the sense of joint movement and body position, and plays an important role in the ability to navigate and interact with the environment. The proprioceptive system involves input from sensory receptors located in the muscles, tendons, and joints, which relay information to the sensory motor cortex regarding joint position, movement, and spatial orientation.

Proprioception is fundamental to our ability to coordinate and execute movements. Whether it is reaching for a glass of water, typing on a keyboard, or running a marathon, the joints rely on sensory feedback from the proprioceptive system to accurately control movement.

Physiological studies reveal a complex interplay between tactile (touch) and proprioceptive inputs in the modulation of the primary motor cortex excitability responsible for execution of voluntary movement. Proprioceptive feedback, particularly when paired with tactile feedback, has been found to have a larger influence on the motor cortex excitability than tactile feedback alone suggesting that the proprioceptive system plays a role in shaping our motor responses and adaptations.[11]

The Casting Motion to Mobilize Stiffness technique (CMMS) is designed to address elements of proprioceptive and tactile feedback, thus promoting sensorimotor organization, normal movement patterns, and improved motor control within the primary motor cortex enhancing motor learning.[1] By addressing proprioception the CMMS approach can lead to improved motor performance and successful rehabilitation outcomes.

SKIN AND ADHESIONS

Skin and adhesions play a pivotal role in the phenomenon of hand stiffness. Scar tissue, resultant from injury or surgery, tends to have reduced flexibility compared to the original tissue, leading to restricted mobility. Furthermore, the formation of adhesions, or bands of scar tissue connecting normally separated anatomical structures, exacerbate the reduction in joint mobility. Addressing these concerns requires interventions directly applied to the skin that can manage scar tissue and improve mobility.

CLINICAL REASONING AND TREATMENT IMPLICATIONS

Fig. 10.1 represents an Algorithm to assist with the clinical reasoning process when implementing treatment for the stiff hand.

INITIAL ASSESSMENT

Pattern Recognition in Motion Evaluation

Evaluating a stiff hand involves understanding the pattern of its movement. This understanding, along with good clinical judgment, can guide us toward a successful treatment plan.

A hand suffering from stiffness, often burdened by swelling and tissue adherence, is typically used less frequently or in altered ways for everyday tasks. When this happens, the brain's usual way of controlling these movements begins to fade. Instead, the brain starts to accommodate these abnormal movements. If these abnormal movement patterns continue, the brain adjusts and makes these movements the new normal. This is a demonstration of "neuroplasticity," which shows how our actions and experiences can lead to both positive and negative changes in our brain.[12]

If stiffness persists, the brain's networks associated with these movements become stronger and more resistant to change. However, research shows that repeated and challenging movements can strengthen these networks and expand the control of the brain. This is seen in Braille readers, who have a more developed brain region for controlling the main muscle of their dominant hand compared to their non-dominant hand or people who don't read Braille.[13]

Addressing joint stiffness requires a strategy that deals with both physical and brain-related aspects. The Casting Motion to Mobilize Stiffness (CMMS) technique, can help reprogram the brain. It does this by dealing with swelling, fibrosis, adherent tissues, and stiffness in multiple joints simultaneously.

From a physical standpoint, the CMMS technique allows movement in two directions, controls swelling through active pumping of lymph fluid, and gives a sort of massage to tissues during active finger movement due to the pressure from the cast.

From a brain-related standpoint, the CMMS technique uses principles of motor learning, encouraging the patient to focus on achieving the intended motion pattern within the cast through regular joint movements. This promotes a normal motion pattern. Moreover, the method uses sensory feedback during mobilization. This feedback boosts brain-spinal cord activity, further emphasizing the importance of engaging both the body and the brain in the process of recovery.

As part of the initial assessment, it is important to use digital photography in addition to taking standard Goniometer measurements. This is because objective means of quantifying the changes in pattern of movement or changes in soft tissue do not currently exist. Direct palpation is the only means of demonstrating the quality of soft tissue change.[6] Digital photography and video recordings ensure accurate recording of observations and changes in pattern of motion and joint mobility.

After identifying the motion pattern and other issues that require attention, it is essential to evaluate whether traditional therapy alone is sufficient to address the presenting problems. Consider if certain joints need immobilization to correct any abnormal movement patterns. Then, assess which additional therapeutic techniques or modalities could be employed, either with or without the CMMS technique.

At the patient's next follow-up appointment, capture new photographs and videos and compare them with those taken during the previous session. Evaluate whether any abnormal movement patterns have resolved or improved and assess the status of joint stiffness. Determine whether the patient is at risk of developing chronic stiffness.

The presence of a dominant motion pattern will guide the subsequent steps. If no abnormal, dominant pattern is observed, continue with traditional therapy. If an abnormal pattern is identified, consider the use of a re-direction orthosis, a metacarpal phalangeal (MCP) joint immobilization cast (typically for single digit stiffness), or CMMS (for multiple digit stiffness). Additionally, consider incorporating any other modalities or techniques that may benefit the patient. This process should be continuously re-evaluated at each consultation. Decisive and immediate action is required if a patient exhibits a dominant abnormal motion pattern or shows signs of developing chronic pain or joint stiffness. In most cases, early implementation of CMMS is advisable. If CMMS is chosen as the intervention, the process should not be rushed. Ensure that the patient has achieved all intended goals before transitioning to the next cast design or beginning the weaning process from the cast.

Practical Applications: Clinical Scenarios of CMMS in Action

Addressing a stiff hand requires a comprehensive strategy that integrates exercises, hands-on therapy techniques, various modalities, and patient education. In this section, each intervention is explained, outlining optimal application to aligning with tissue tolerance while considering healing timelines.

Special emphasis is given to the CMMS technique due to its utility and gentleness on the tissue and lymphatic system, which reduces the risk of injury from overzealous therapy. This technique, based on the rationale described above, is prioritized and recommended as the treatment of choice for recalcitrant the stiff hand.

To demonstrate the practical application of the CMMS technique, four clinical scenarios are introduced. Each case presents unique challenges concerning joint stiffness.

Through these examples, the versatility and efficacy of the CMMS technique are highlighted, demonstrating the capacity to treat a single stiff joint or a devastating hand injury involving multiple joints. Tables 10.1–10.3 provide the details for each case: patient synopsis, treatment rationale, therapeutic modalities, and techniques relative to the stages of wound healing. These cases demonstrate the importance of blending techniques to achieve desirable outcomes.

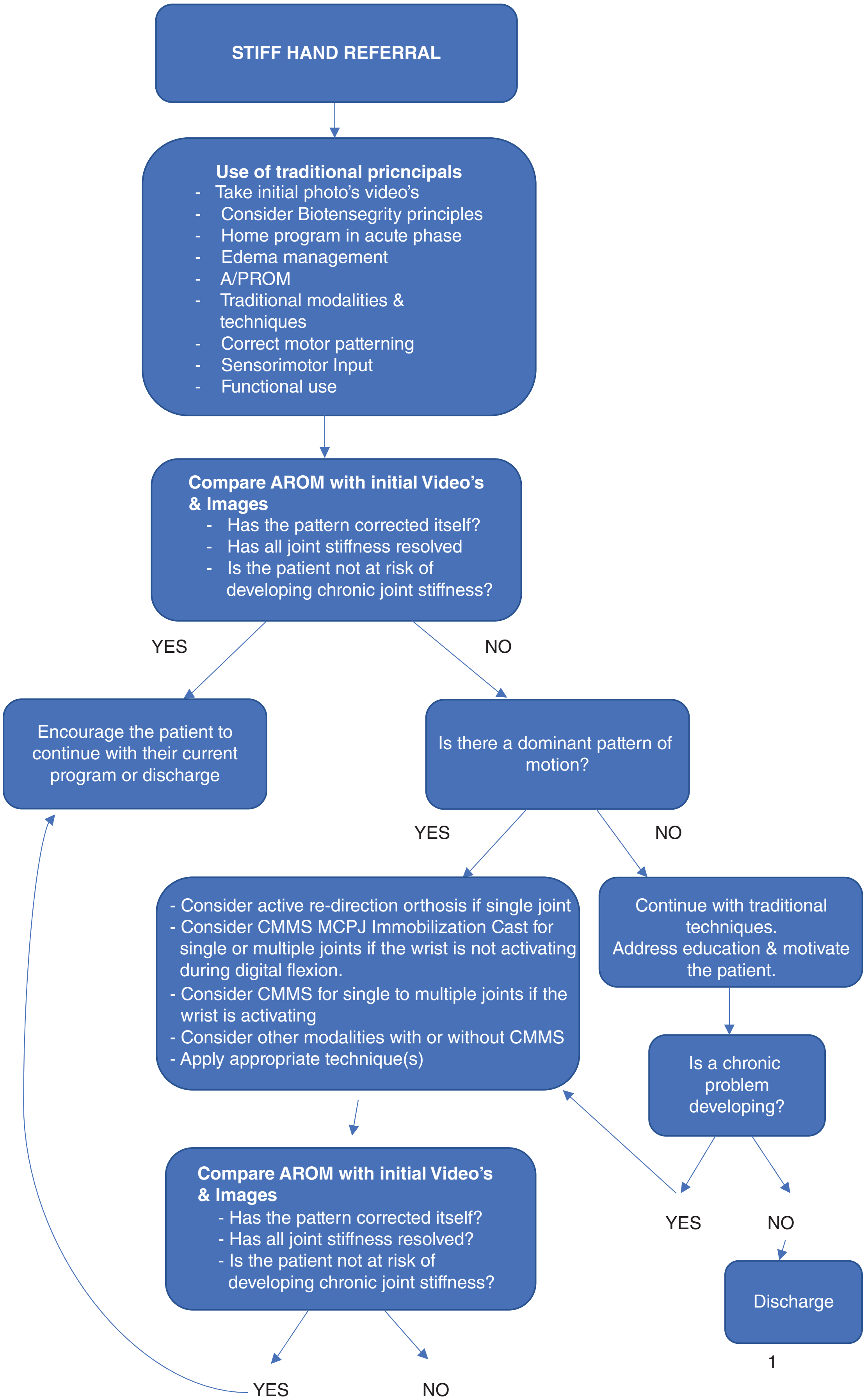

Fig. 10.1 Clinical reasoning algorithm.

CASE STUDY 10.1 Bilateral Multiple Dog Bite Wounds Demonstrating the Initial Puncture Wounds, CMMS Casts Provided, and the Results

Case Overview

S was attacked by a small dog during training. The dog attacked both hands, puncturing the left hand in 6 places and the right hand in 14 places. S has a history of pre-existing Brachial Neuritis and persistent meningitis, managed with medication. He presented to hand therapy in the proliferative phase of tissue healing with wound sutures in situ and bilateral multiple joint stiffness (Figs. 10.2–10.4), a dominant intrinsic plus pattern of motion in the left and right hands, tissue adherence, persistent inflammation, edema, and pain. In addition, the medial and lateral branches of the superficial branch of the radial nerve were tensioned by scar tissue (Video 10.1).

Fig. 10.2 Left hand volar view—initial presentation.

Fig. 10.3 Left hand dorsal view—initial presentation.

Fig. 10.4 Right hand volar view.

CMMS Rationale and Intervention

S was seen during the early, middle, and late phases of rehabilitation, coinciding with the proliferative and remodeling stages of tissue healing. He presented with bilateral joint stiffness with an abnormal dominant intrinsic plus pattern of motion in both hands. The right hand activated the wrist flexors during digital flexion, making it necessary to stabilize the wrist to direct motion on the stiffest joints. The CMMS technique was prioritized over traditional therapy to address multiple problems simultaneously and was applied for 3 months (Figs. 10.5–10.8 and Tables 10.2A,B and 10.3). An intrinsic minus cast was initially provided to improve digital stiffness and was worn for 4 weeks. Once the stiffness resolved, an intrinsic plus cast was provided for another 4 weeks to regain the residual loss of motion in the hand. This cast was made into a bivalve cast for the cast weaning phase, which required 4 weeks of intermittent use. CMMS was used for a total of 3 months. On the left hand, the patient presented with a dominant intrinsic minus pattern of motion due to scarring on the dorsal and volar aspects of the 5th MCP joint. In order to achieve full MCP joint flexion, this scar tissue needed to be reduced while the patient actively mobilized the digits into a hook fist position. Since the wrist flexors were not activating during digital flexion and the limited MCP joint flexion was due to scar tissue, a hand-based MCP joint immobilization cast was provided instead of an intrinsic minus cast. Joint stiffness and tissue adherence resolved within 4 weeks.

Potential tissue tolerance warning signs were considered throughout the course of treatment (Table 10.2) but did not flare up as the CMMS technique provides non-aggressive therapeutic intervention while providing adequate stress to the tissues. In addition to CMMS, a variety of therapeutic techniques and modalities were used to assist the healing process (Table 10.3). Video 10.1 (supplementary material) demonstrates and explains the abnormal movement patterns, the CMMS immobilization casts that were used and the therapeutic techniques required to improve active range of motion.

Continued

CASE STUDY 10.1 Bilateral Multiple Dog Bite Wounds Demonstrating the Initial Puncture Wounds, CMMS Casts Provided, and the Results—cont'd

Fig. 10.5 Left MCPJ cast.

Fig. 10.7 Right intrinsic plus cast progress.

Fig. 10.6 Right intrinsic minus cast.

Fig. 10.8 Bivalve cast.

CASE STUDY 10.1 Bilateral Multiple Dog Bite Wounds Demonstrating the Initial Puncture Wounds, CMMS Casts Provided, and the Results—cont'd

Results and Discussion

Full digital motion and functional use were regained in both the left and right hands through the use of the CMMS technique and selected therapeutic modalities and techniques (Fig. 10.9). The treatment duration of 3 months was less than expected compared to traditional therapy.

Key Takeaways

- The deep dog puncture wounds elicit trauma that is not evident on the surface of the skin but exists deep into the tissue. Puncture wounds create a risk of scar tissue which can impair joint mobility.
- The skin becomes adherent to underlying scar tissue and the cutaneous nerves, which in turn impair thumb motion.
- With bilateral hand injuries, both circumferential and bivalve casts are used to permit personal care. The less problematic hand should have a removable cast.
- The CMMS technique expediated the treatment process.

Fig. 10.9 Left and right hand result.

CASE STUDY 10.2 Distal Radius Fracture Injury Demonstrating the Initial Pattern of Motion, Cast Designs, and the Results

Case Overview

B was referred to hand therapy during the initial COVID lockdown. He sustained a severe Distal Radius Fracture to his left non-dominant hand with multiple comminuted fragments. The fracture was initially managed non-operatively. However, 2 weeks later, the radius shortened, and an Open Reduction with Internal Fixation was performed. He was referred to hand therapy once the cast was removed during the proliferative phase and presented with multiple stiff and swollen fingers and limited wrist range of motion in all directions (Fig. 10.10 and Video 10.2). B was immunocompromised during the COVID-19 pandemic due to recent open heart surgery. Therefore, it was necessary to apply a technique that minimized hand therapy appointments to avoid exposure to COVID-19.

CMMS Rationale and Intervention

B presented with a dominant intrinsic plus pattern of motion and multiple joint stiffness with early signs of hand disuse and trophic skin changes. A resting tremor indicated signs of nerve tension and muscle weakness (Table 10.2). The CMMS technique was selected to lower the risk of exposure to COVID and to expedite his return to function through selective immobilization of proximal joints to direct distal motion to the stiff digits. The stiff wrist, although a concern, was not prioritized over digital motion in the early rehabilitation phase. Once digital stiffness resolved, wrist motion was addressed.

An intrinsic minus cast (Fig. 10.11) was applied to regain full AROM of the stiff digits I–IV. After 2 weeks digital stiffness resolved. This cast was removed and an intrinsic plus cast (Fig. 10.12) was applied for an additional 2 to regain full MCP joint flexion. Cast weaning began at week 4 for 2 weeks.

Fig. 10.10 Initial AROM.

Fig. 10.11 Intrinsic minus cast.

Continued

CASE STUDY 10.2 Distal Radius Fracture Injury Demonstrating the Initial Pattern of Motion, Cast Designs, and the Results—cont'd

Fig. 10.12 Intrinsic plus cast.

A variety of additional therapeutic techniques and modalities were used to facilitate healing (Table 10.3), taking the rehabilitation and tissue healing phases into consideration (Table 10.3). Video 10.2 demonstrates the full rehabilitation progression, including the proprioceptive wrist rehabilitation program and the late rehabilitation phase where advanced wrist strengthening exercises were performed (Video 10.2).

Results and Discussion

B regained full AROM of his wrist (Fig. 10.13) and digits and was able to perform advanced wrist and upper extremity strengthening exercises. Although joint stiffness resolved in the first 4 weeks of treatment, an additional 6 weeks were needed to fully rehabilitate his wrist.

Key Takeaways

- Immunocompromised patients benefit from the CMMS technique due to a decreased risk of exposure as fewer hand therapy appointments are needed.
- Effective resolution of joint stiffness permits relatively early implementation of advanced strengthening and return to function programs.

Fig. 10.13 Result.

CASE STUDY 10.3 Proximal Interphalangeal Joint (PIP) Joint Dislocation Injury Demonstrating the Initial Deformity, Cast Designs, and the Results

Case Overview

Mr H fell while doing a handstand resulting in a left ring finger dislocation at the PIP joint. Radiographs confirmed no fracture. He was referred to hand therapy for management of the left ring finger.

CMMS Rationale and Intervention

H presented with a 30-degree fixed flexion deformity of the left ring finger PIP joint with poor digital flexion (Fig. 10.14). A serial Plaster of Paris serial cast (Fig. 10.15) was provided as described by Colditz.[1] The cast was worn for 5 days. Following its removal, a dorsal night extension splint was provided to maintain motion in finger extension. In addition, an MCP joint immobilization cast was provided to improve flexion of the PIP and DIP joints (Fig. 10.16). The MCP immobilization cast is removable, and can adequately immobilize the powerful MCP joints in order to direct motion to the stiff PIP and DIP joints. Patients are instructed to engage their brain by actively focusing on joint motion to ensure an adequate hook fist position during the cyclical repetitive motion of all the fingers working together. H was also encouraged to actively extend the PIP joint against the hood of the cast. The cast is effective in

CASE STUDY 10.3 Proximal Interphalangeal Joint (PIP) Joint Dislocation Injury Demonstrating the Initial Deformity, Cast Designs, and the Results—cont'd

Fig. 10.14 Initial AROM.

Fig. 10.15 POP finger extension cast.

Fig. 10.16 POP MCPJ immobilization cast.

exercising the joint in both directions. A variety of therapeutic modalities and techniques (Table 10.3) were used to aid healing of the UCL ligament.

Results and Discussion

The PIP joint flexion deformity resolved with 1 serial cast in 5 days (Fig. 10.17). An additional 5 weeks of exercising within the MCP joint immobilization cast were needed to regain full flexion and extension of the PIP joint (Fig. 10.17 and Video 10.3). Patients find it beneficial if the collateral ligaments are supported with kinesio tape (80% stretch). IASTM assists with releasing the fascia and the underlying cutaneous nerves from the skin, thereby aiding joint mobility. The tuning forks applied to the UCL injury helps to reduce pain and inflammation. These techniques, coupled with CMMS, expedite healing significantly.

Key Takeaways

- Resolve the PIP joint extension contracture to improve extension first before proceeding to improve joint mobility.
- Apply a dorsal night splint to maintain joint extension.
- Use the MCP joint immobilization cast to address digital flexion.
- Encourage continuous use of the MCP joint immobilization cast
- Combine other treatment techniques that will facilitate healing.

Continued

CASE STUDY 10.3 Proximal Interphalangeal Joint (PIP) Joint Dislocation Injury Demonstrating the Initial Deformity, Cast Designs, and the Results—cont'd

Fig. 10.17 Result.

CASE STUDY 10.4 Boxers Fracture Injury Demonstrating the Initial MCP Stiffness, Cast Provided, Rotational Deformity Correction, and the Results

Case Overview

T sustained a boxer's fracture to the 5th Metacarpal of his dominant hand 3 years prior to being referred to hand therapy. Previous therapy did not improve the joint stiffness (Fig. 10.18). He presented to hand therapy with 20 degrees of MCP joint flexion and a rotational deformity of the ring finger.

CMMS Rationale and Intervention

The CMMS technique was selected to resolve the MCP joint stiffness because it provides a prolonged, sustained stretch to the skin on the dorsum of the hand. In addition, it provides a gentle distal glide of the skin and positions the MCP joints in flexion using the intrinsic plus cast (Fig. 10.19), thereby facilitating flexion away from the hood of the cast (Video 10.4). Elastic tape was applied to the ring finger to correct the alignment of the joint (Fig. 10.20).

Fig. 10.18 Initial AROM.

Results and Discussion

The CMMS technique provides effective treatment for chronic MCP joint stiffness because the MCP joint is positioned at maximum range with the assistance of the distal skin glide from the cast. Patients find this positioning provides the sensory feedback required to move in the direction needed to regain joint motion. The elastic tape fully resolved the rotational deformity of the ring finger (Fig. 10.21). T achieved the desired result within 3 days and then used a bivalve cast for an additional 4 weeks for maintenance. It is important to note that if the cast is abandoned too soon, the joint stiffness returns.

Key Takeaways

- The Intrinsic plus cast is effective in resolving chronic MCP joint stiffness.
- No force or flexion strapping is required.
- Active motion alone is sufficient to achieve the desired result.
- Elastic taping can effectively resolve rotational deformities. The combination of elastic taping and CMMS is effective.
- Weaning is essential to ensure that results are maintained long term.
- Only 3 sessions were needed after 3 years of joint stiffness.

Fig. 10.19 Intrinsic plus cast and rotational deformity.

CASE STUDY 10.4 Boxers Fracture Injury Demonstrating the Initial MCP Stiffness, Cast Provided, Rotational Deformity Correction, and the Results—cont'd

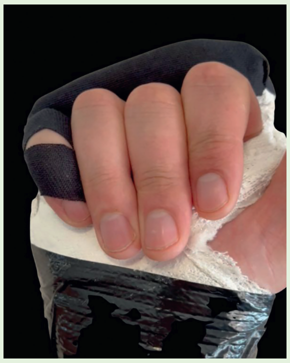

Fig. 10.20 Corrected rotational deformity.

Fig. 10.21 Result.

TABLE 10.1 Patient Synopsis

Case Study	Diagnosis	Sex	Dominance	Injured Side	PAST Medical History	Occupation	Duration of Treatment	Number of Sessions	Outcome Video Number
1	20 Dog Bite Wounds	M	Right	Left & Right	Brachial Neuritis Persistent Meningitis	Dog Trainer	7 Months	22	1
2	Distal Radius Fracture	M	Right	Left	COVID	Retired	2.5 Months	13	2
3	PIP Joint Dislocation	M	Right	Left	N/A	Information Technology	6 Weeks	6	3
4	Boxers Fracture	M	Right	Right	N/A~	Student	1 Month	3	4

TABLE 10.2A Impairment, Rehabilitation Phase and Tissue Healing Rationale

Case Study	Impairment & Functional Limitations Pre Treatment	Rehabilitation Phase	Tissue Healing Phase	Tissue Tolerance Warning
1 Dog Bite	Bilateral multiple joint stiffness Abnormal Pattern of Motion bilaterally Multiple dog puncture wounds bilaterally Inflammation & Edema Tendon adherence	Early Rehab Phase: 2–3 weeks	Proliferative	Increased Pain Persistent Oedema Increased Inflammation Persistent Joint Stiffness
	Medial branch of SRN tensioned under scar Lateral branch of SRN tensioned under scar	Middle Rehab Phase: 2–3 months	Remodeling	Scar Tissue Formation
		Late Rehab Phase: 3–6 months	Remodeling	Increased Pain Persistent Oedema Increased Inflammation
2 Distal Radius Fracture	Poor wrist AROM Multiple joint stiffness Abnormal pattern of motion Persistent edema Trophic skin changes	Early Rehab Phase: 2–3 weeks	Proliferative	Increased Pain Persistent Oedema Increased Inflammation Persistent Digital Stiffness
	Poor strength Poor functional use		Remodeling	Persistent MCPJ Stiffness
3 PIPJoin Dislocation	30-degree fixed flexion deformity of the ring finger UCL tear Rotational deformity of the ring finger Poor digital flexion of the ring finger Poor functional use Poor strength	Middle Rehab Phase: 2–3 months	Remodeling	Increased Pain Persistent Oedema Increased Inflammation Persistent Joint Stiffness
4 Boxers Fracture	3 year old injury Adherent scar tissue over the dorsum of the 5th Metacarpal Stiff 5th MCPJ	Late Rehab Phase: 3 years	Remodeling	Increased Pain Persistent Joint Stiffness

TABLE 10.2B **CMMS and Therapeutic Modalities Treatment Rationale**

Case Study	Treatment Left Hand	Rationale	Treatment Right Hand	Rationale	Figure Number	Video Number
1 Dog Bite Early Rehab Phase	CMMS Technique MCP Joint Immob Cast (Fig. 10.4) Therapeutic Modalities (Table 10.3)	Not activating wrist flexors Dominant intrinsic minus pattern Adherent scar over dorsal and volar 5th MCPJ Scar tissue preventing MCPJ motion	CMMS Technique Intrinsic Minus Cast (Fig. 10.5) Therapeutic Modalities (Table 10.3)	Activating wrist flexors Dominant Intrinsic plus pattern Swollen, inflamed, and stiff thumb Multiple puncture wounds	1–8	1
Middle Rehab Phase	Continue with MCP Joint Immob Cast Therapeutic Modalities (Table 10.3)	Resolved pattern of motion & digital stiffness Stiff MCPJ's therefore make Intrinsic Plus Cast	Intrinsic Plus Cast (Fig. 10.6) Therapeutic Modalities (Table 10.3)	Gained control of wrist flexors Normal pattern of motion not established		
Late Rehab Phase	Therapeutic Modalities (Table 10.3)	Begin Cast weaning Begin Strengthening	Bivalve Cast Fabricated (Fig. 10.7) Therapeutic Modalities (Table 10.3)	Established pattern of motion Begin strengthening		
2 Distal Radius Fracture Early Rehab Phase	CMMS Technique Intrinsic Minus Cast (Fig. 10.11) Therapeutic Modalities (Table 10.3)	Activating wrist flexors Dominant Intrinsic plus pattern Multiple joint stiffness Tremor due to weakness and nerve tension			9–12	2
Middle Rehab Phase	Intrinsic Plus Cast (Fig. 10.12, week 2-4) Begin CMMS weaning (week 4) Begin strengthening (week 6) Wrist Proprioceptive program (week 8) Functional Re-Training (week 10)	CMMS resolved joint stiffness within 1 month To regain full functional use To target sensory-rich ligaments in the wrist. To restore confidence and function				
3 PIP Joint Dislocation Middle Rehab Phase	5 days in PIP serial cast (Fig. 10.14) MCPJ Immobilization cast (Fig. 10.15) Therapeutic Modalities (Table 10.3)	Correct ring finger extension prior to flexion Dominant intrinsic plus pattern of motion UCL tear			13–16	3
4 Boxers Fracture Late Rehab Phase			CMMS Technique Intrinsic Plus Cast (Fig. 10.18)	Static, prolonged positioning needed to resolve long standing joint stiffness	17–20	4

TABLE 10.3 **Overview of Therapeutic Modalities and Techniques Used**

Case Study	Precaution	Applied	Tissue Precaution	Therapeutic Interval	Frequency	Intensity	Duration
Case Study 10.1	Compromised Immune System						
Education		✓		Duration of treatment			
Joint Mobilisation	Tissue tolerance	✓	Pain free only	Between cast changes	Intermittent	Mild	5 minutes
AROM Exercises		✓		In CMMS cast	Constant, cyclical, repetitive motion with rest	High	3 months
Splinting							
Nerve Glide Exercises							
Tendon Glide Exercises							
Heat							
Ice	10 minutes	✓		Early phase	0–2 weeks, at therapy session		3 minutes
Contrast baths		✓		Early phase	0–4 weeks, 1 x per day		6 minutes
Vibration or Massage		✓					
Compression Therapy		✓		Early phase			
Kinesio Tape	Skin irritation	✓					
IASTM		✓		Middle - late phase	1 x per day Pt taught to perform		10 minutes
CMMS	Infection	✓		Initiated Early - late phase			
MCP Joint Immob Cast		✓		Early - middle phase	Constant, cyclical, repetitive motion	High	1 month
Intrinsic Minus		✓		Early - middle phase	Constant, cyclical, repetitive motion	High	1 month
Intrinsic Plus Cast		✓		Early - middle phase	Constant, cyclical, repetitive motion	High	1 month
Bivalve		✓		Middle - late phase	Constant, cyclical, repetitive motion	High	1 month
Cast Weaning		✓		Late phase	Intermittent cast use with increased functional use.	High	1 month
Strengthening				Late phase	Theraputty	Low	10 minutes per day
Case Study 10.2	Compromised Immune System						
Education		✓		Duration of treatment			
Joint Mobilisation		✓	Pain free only	Post CMMS	At Therapy session to mobilize the wrist	Mild	10 minutes
AROM Exercises		✓		Within the cast	Constant, cyclical, repetitive motion	High	1 month
Splinting							
Nerve Glide Exercises							
Tendon Glide Exercises							

Continued

TABLE 10.3 Overview of Therapeutic Modalities and Techniques Used—cont'd

Case Study	Precaution	Applied	Tissue Precaution	Therapeutic Interval	Frequency	Intensity	Duration
Heat		✓		Late phase	Pre wrist PROM and AROM exercises	Mild	10 minutes
Ice							
Contrast baths		✓		Early Phase Pre Casting	1 x per day Pt taught to perform	Mild	6 minutes
Vibration or Massage		✓					
Compression Therapy		✓		Early - Middle Phase			10 minutes
Kinesio Tape		✓		Early - Middle Phase	Applied to Index Finger to aid AROM for 2 weeks	High	2 weeks
IASTM							
CMMS		✓		Initiated Early Phase			
MCP Joint Immob Cast							
Intrinsic Minus Cast		✓			Constant, cyclical, repetitive motion	High	2 weeks
Intrinsic Plus Cast		✓			Constant, cyclical, repetitive motion	High	2 weeks
Bivalve Cast		✓		Middle phase	Constant, cyclical, repetitive motion	High	2 weeks
Biometrics E Link		✓		Late Phase	1 x per week at therapy session	Moderate	30 minutes
Functional Training		✓		Late Phase	3 x per week HEP	Moderate	30 minutes
Strengthening		✓		Late Phase	Theraputty & Theraband 10 minutes per day	Low	10 minutes per day
Case Study 10.3	None						
Education		✓		Early Phase			
Joint Mobilisation		✓		Early Phase	Passive within the serial cast & active within the MCP joint cast	High	
AROM Exercises		✓			Within the MCP joint cast	High	
Splinting		✓		Early Phase	Dorsal finger extension splint at night	High	At night to maintain ROM
Nerve Glide Exercises							
Tendon Glide Exercises		✓		Early Phase	Outside of the cast at least once a day	Low	
Heat							
Ice		✓		Early Phase	Ice probe massage in therapy		
Contrast baths							
Vibration or Massage							
Vibration or Massage							
Kinesio Tape		✓		Early Phase	Taping to support the collateral ligaments		
IASTM		✓					
CMMS		✓		Initiated Early Phase			

TABLE 10.3 **Overview of Therapeutic Modalities and Techniques Used—cont'd**

Case Study	Precaution	Applied	Tissue Precaution	Therapeutic Interval	Frequency	Intensity	Duration
PIP Joint Serial Cast		✓		Early Phase	Static serial cast for 5 days	High	5 days
MCP Joint Immob Cast		✓		Early Phase	Constant, cyclical, repetitive motion	High	4 weeks
Intrinsic Minus Cast							
Bivalve Cast							
Biometrics E Link							
Functional Training							
Strengthening		✓		Middle Phase	Theraputty	Low	10 minutes per day
Case Study 10.4	None						
Education		✓		Early Phase			
Joint Mobilisation							
AROM Exercises		✓		Late Phase	Constant, cyclical, repetitive motion	High	4 weeks
Splinting							
Nerve Glide Exercises							
Tendon Glide Exercises							
Heat							
Ice							
Contrast baths							
Vibration or Massage							
Vibration or Massage							
Kinesio Tape							
IASTM							
CMMS		✓		Initiated Late Phase			
PIPJ Serial Cast							
MCPJ Immob Cast							
Intrinsic Minus Cast							
Intrinsic Plus Cast		✓		Late Phase	Constant, cyclical, repetitive motion	High	4 weeks
Bivalve Cast		✓		Late Phase	Constant, cyclical, repetitive motion	High	4 weeks
Biometrics E Link							
Functional Training							
Strengthening		✓		Late Phase	Theraputty	Low	10 minutes per day

SUMMARY

Joint stiffness is a complex issue that involves mechanical, cerebral, and biological factors. Effective treatment requires a comprehensive approach that addresses all factors simultaneously. Overaggressive therapy and splinting, can exacerbate stiffness and potentially harm tissues. The CMMS Technique is effective for managing the stiff hand. Early application of the CMMS technique can avoid chronic stiffness and prevent the development of conditions like Complex Regional Pain Syndrome (CRPS).

CMMS, with its focus on restoring normal movement patterns, aims to reduce joint stiffness and improve functional outcomes. This is achieved by harnessing the brain's neuroplasticity, which allows the reorganization of the motor cortex to adapt to new patterns of movement. By adopting normal movement patterns, patients actively participate in their recovery, enhancing rehabilitation outcomes and minimizing the likelihood of recurring stiffness.

Therapeutic techniques and modalities should not be selected in isolation but utilized in conjunction with CMMS for maximum efficacy. The most effective management of the stiff hand lies not just within the confines of therapy sessions, but rather in the sustained intervention strategies implemented between these sessions through tools such as CMMS casts allowing for continuous treatment.

This chapter emphasized that managing joint stiffness is a complex task requiring a delicate balance of various treatment modalities. However, with early and effective intervention strategies such as CMMS joint stiffness can be effectively managed and mitigated.

Key Terms

- **Casting Motion to Mobilize Stiffness Technique (CMMS):** Involves selectively immobilizing certain joints using a cast to facilitate the recovery of motion in other stiff joints.
- **Viscoelastic:** Refers to a property of materials that exhibit both viscous (resistance to shear flow) and elastic (tendency to return to original shape after deformation) characteristics when undergoing deformation

Definitions

- **Phagocytosis** refers to the process in which certain living cells called phagocytes engulf other cells, particles, or pathogens to destroy them. This is a crucial mechanism in the immune response to infection.

REFERENCES

1. Colditz JC: Plaster of paris: the forgotten hand splinting material, *J Hand Ther* 15:144–145, 2002.
2. Sharkey J: Biotensegrity—the structure of life. In Lesondak DR, Schleip R, editors: *Fascia, function, and medical applications*, ed 1, 2020, Boca Raton, Florida, USA: CRC Press.
3. Midgley R, Pisano K: Therapists' management of the stiff hand. In Skirven TM et al., editors: *Rehabilitation of the hand & upper extremity*, ed 7, Philadelphia, PA, 2020, Elsevier Mosby.
4. Kielty CM, Sherratt MJ, Shuttleworth CA: Elastic fibers, *J Cell Sci* 115(Pt 14):2817–2828, 2002.
5. Mierke CT: Viscoelasticity, like forces, plays a role in mechanotransduction, *Front Cell Dev Biol*, 2022 10:789841. https://doi.org/10.3389/fcell.2022.789841.
6. Midgley R: The use of CMMS (Casting Motion to Mobilise Stiffness) to regain digital flexion following Dupuytren's fasciectomy, *Hand Ther* 15(19):45–51, 2010.
7. Shoulders MD, Raines RT: Collagen structure and stability, *Annu Rev Biochem* 78:929–958, 2009. https://doi.org/10.1146/annurev.biochem.77.032207.120833.
8. Pascual-Leone A, Amedi A, Fregni F, Merabet LB: The plastic human brain cortex, *Annu Rev Neurosci* 28(1):377–401, 2005. https://doi.org/10.1146/annurev.neuro.27.070203.144216.
9. Campos AC, Groth AK, Branco AB: Assessment and nutritional aspects of wound healing, *Curr Opin Clin Nutr Metab Care* 11(3):281–288, 2008.
10. Cyr LM, Ross RG: How controlled stress affects healing tissues, *J Hand Ther* 11(2):125–130, 1998.
11. Vanzino L, Pelosin E, Abbruzzese G, Bassolino M, Pozzo T, Bove M: Shaping motor cortex plasticity through proprioception, *Cereb Cortex* 24(10):2807–2814, 2014.
12. Kleim JA, Thomas J: Principles of experience-dependent neural plasticity: implications for rehabilitation after brain damage, *J Speech Lang Hear Res* 51(1):225–239, 2008.
13. Pascual-Leone A, Cammarota A, Wassermann EM, Brasil-Neto JP, Cohen LG, Hallett M: Modulation of motor cortical outputs to the reading hand of braille readers, *Ann Neurol* 34(1):33–37, 1993.